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THE EFFECT OF TEMPERATURE AND HUMIDITY ON THE TOBACCO POWDERY MILDEW FUNGUS

[Following is a translation of an article by D. J. Rossouw, Central Institute for Tobacco Investigation, Rustenburg, in the Afrikaans-language periodical Suid-Afrikaanse Tydskrif vir Landbouwetenskap (South-African J. Agr. Sci.) Vol. 2, No 1, 1959, pp 19-31)

The germination of conidia of Erysiphe cichoracaerum of tobacco on dry glass plates is determined. The most important temperatures are as follows: minimum, lower than 5°C; optimum, 24-25°C, and maximum, 30-35°C. Conidia of the fungus germinate at 0 to 100 percent relative humidity at temperatures between 15° and 30°C.

The most important temperatures for the development of powdery mildew of tobacco are: minimum 5°C., optimum 23.5°C., and maximum 25°C.

The temperature and the relative humidity of some tobacco-producing regions inside and outside the Union of South Africa and the existence of powdery mildew in those regions is determined; it shows that the fungus does not exist in regions with an average daily temperature of 25°C and higher. The relative humidity apparently plays a less important part in the origin, development and spread of the fungus disease.

Introduction

Powdery mildew without doubt causes one of the most important and harmful diseases of tobacco in certain parts of the Union of South Africa. It causes yearly losses that can amount in some cases to 30 percent of the total harvest.

Although as a fact the disease exists in all parts of the world where tobacco is raised, yet it is not everywhere equally harmful. Just as in the Union of South Africa where there are regions where the powdery mildew is of utmost economical importance, there are other regions where no harm is done.

In the tobacco-producing districts of Rustenburg, Brits, Globersdal and Potgietersrust, for instance, the disease is generally present, while tobacco grown in the districts of Orighstad and Pongola is only slightly affected, and it is unknown in the Komatipoort district.

The question to be answered is why the disease in certain parts is serious and absent in other regions.

Procedure

The germination of conidia of Erisyphe cichoracearum is determined as follows. To obtain a right amount of spores to be used in the experiments the tobacco plants, in pots, were kept during seven days in climate rooms under artificial light. The result was that abundant sporulation took place on the plants in such rooms, where the temperature was kept between 17-22°C.

A reasonably equal dispersion of conidia could be realised by pressing slides lightly on the spore colonies. It showed that when the slides were pressed on the colonies with too much force, too many old, shrunken spores, unable to germinate, were glued to the slides.

The slides with conidia were immediately placed in open Petri dishes. After this the dishes were placed in closed containers under certain conditions and kept for 24 hours in incubators at a certain temperature. Every experiment was repeated three times and every time approximately 200 spores were counted. The germination percentage at every temperature and relative humidity thus was calculated at an average of six hundred spores.

After germination the conidia are killed by staining with a 5 percent solution of cottonblue and lactophenol. This way there was enough time for the right performance of the experiments and further germination of the spores after the slides were removed from the experimental circumstances was avoided; besides, the counting of the germinating spores was much easier.

The development of the fungus on the tobacco plant was studied in climate rooms (Pearse, 1955) under artificial light. All possible precautions were taken to be sure that the plants were absolutely free from powdery mildew contamination. Tobacco plants in pots, for, instance were for two weeks every other day sprayed with caratane powder and then thoroughly washed. After this the plants were, during at least two weeks, regularly sprayed with clean water. Plants treated this way were inoculated and placed in different climate rooms at temperatures, respectively, of 5, 13, 17, 20, 23.5 and 25°C. The surface of the leaves of a plant was calculated by the method of Lal and Subba (1951), the number of colonies on the plant counted and the contamination per square inch calculated.

Results

The effect of temperature on the germination of conidia of Erysiphe cichoracearum is shown in Table I.

Table I. The percentage of germination of conidia of Erysiphe cichoracearum at different temperatures in a saturated atmosphere.

Temperature	Germination
degrees centigrade	percentage
5	1.9
10	14.3
15	19.5
20	50.3
22	55.0
24	60.9
25	61.6
26	43.0
30	10.4
35	0.0

The results show clearly that:

(i) Spore germination is at its best between 24–25°C;
(ii) Percentage of germination is minute at 5°C, but at least 10% of the spores still germinate at both 10°C and 30°C.
(iii) No germination at 30°C.

The result of the experiments to determine the amount of conidia of the powdery mildew fungus germinating at 10°C, 15°C, 20°C, 22°C, and 25°C, is shown in Figure I. [Fig. 1 not shown in source.]

The obtained results show clearly that:

(i) Most of the spores germinate at 25°C.
(ii) More than 90 percent of the spores germinate within ¼ hours at 25°C, 22°C, and 20°C, and more than 30 percent at 10°C in the same time.
(iii) The spores relatively soon germinate because a reasonable amount of germination at all these temperatures exists already after a period of three hours.

The development of the powdery mildew disease of tobacco under artificial light is shown in Figure 2. [Fig. 2 not shown in source.]

Table 2. The percentage germination of conidia of the tobacco powdery mildew fungus at different temperatures and relative humidities after 24 hours.

	Percentage germination at different temperatures				
Relative Humidity	15°C	22°C	25°C	26°C	30°C
100.0	19.5	55.0	61.6	43.0	10.4
89.9	15.6	35.0	56.7	41.1	10.6
78.7	9.1	33.5	49.5	28.0	15.3
70.4	10.1	41.9	34.9	24.9	18.0
42.0	6.1	19.3	21.4	14.-	12.5
0.0	4.6	13.5	16.3	14.0	3.0

The data of Table 2 allow the following conclusions:

(i) That in accordance with a diminishing of relative humidity from 100 percent to 0.0 percent a decrease of germination at certain temperatures is clearly shown.

(ii) That a reasonable amount of germination (3.0-16.3 percent) exists even at a relative humidity of 0 percent.

(iii) That the optimum temperature for spore germination at a fixed percentage was found between 22°C and 26°C and in fact close to 25°C.

(iv) That the germination diminishes much at a certain percentage of relative humidity when the temperature of 25°C, for instance, is raised to 30°C or lowered to 15°C.

Review

The purpose of this investigation was to determine the effect of temperature and humidity on the growth and development of the powdery mildew fungus and to find, if possible, the explanation why the disease is a serious problem in some tobacco-producing districts and is not present at all in other districts.

A. Temperature

The cardinal temperatures for spore germination are: minimum, lower than 5°C, optimum 24-25°C, and maximum 30-35°C. The gap between the temperatures in which germination is possible seems to be much wider than it is for contamination of the plant by the fungus. For instance, no contamination at all at a constant experimental temperature of 5°C and 25°C or higher; the optimum temperature for contamination was around 23.5°C. Although no contamination took place at 5°C, this temperature was for the fungus not deadly, because when the plant was contaminated before and after it was placed at a temperature of 5°C and at 25°C, the fungus died at the 25°C temperature and not at the 5°C temperature. The

results are very well in adcordance with those of Levijkh (1940) as to the minimum, optimum and maximum temperatures, which were respectively 10°C, 16-24°C, and 26°C.

The contamination of tobacco by powdery mildew takes place at a much lower temperature than the temperature at which the plant normally grows. The fungus is killed by temperatures of 25°C and higher, which does not seem detrimental to the plant. This conclusion is more or less in accordance with the experience of Delp (1954) as to powdery mildew on grapes.

A comparison of the average temperatures in some tobacco-producing regions in and outside the Union of South Africa shows that the average of the daily minimum-maximum temperature in those regions is connected with the cardinal temperature for contamination with powdery mildew.

For the purpose of this investigation the climate and the presence or absence of powdery mildew was studied in the following countries and regions: North Carolina (US), Sumatra, Java, Marandellas (South Rodesia) and the Union of South Africa.

In the Union of South Africa Virginia tobacco is produced in central, North and East Transvaal, the southwest and east districts of Cape Province and the coastal districts of Natal. The climate in these regions varies from tropical to sub-tropical and the tobacco regions are usually situated lower than 4000 feet above sea level.

In the Federation of Rhodesia and Nyassaland one of the biggest producers of tobacco in the world, the tobacco is grown up to a height of 5000 feet above sea level.

The raising of tobacco in the East Indian islands during the Dutch reign was mostly done in the lower parts. On Sumatra tobacco is seldom raised at a higher level than 650 feet above sea level. The indigenous tobacco locally used by the population is grown inland at higher places; the tobacco on Java again between 400 and 1800 feet above sea level.

The US produces tobacco from the southern part of Wisconsin and Connecticut Valley to the northern part of Florida. The temperature during the growing season varies from 21.1 to 25.3°C. In the central parts with the biggest production the average temperature is 24.5°C or a little higher.

As the powdery mildew disease does not exist in some regions and countries an investigation took place to determine whether there is a correlation between the temperatures in different tobacco-producing countries and the presence or absence of the disease. The results of the investigation as to the temperatures only is shown in Table 3.

Data in relation to the presence of powdery mildew in regions and countries outside the Union of South Africa (Table 4) is obtained from publications (D'Angremond, 1923; Swart, 1934; Wolf, 1935 and Hopkins, 1956.)

Data with respect to the tobacco disease in the Union of South Africa were observed by the author. The data are shown in Table 4.

Table 4. The degree of development of powdery mildew in different localities and countries in which tobacco is grown.

Country	Locality	Degree of development of the disease
Union of South Africa	Rustenburg	+ + +
	Pongola	+
	Komatipoort	-
USA	North Carolina,	-
Sumatra	Medan	-
	Fort de Kock	+ + +
Java	Pandang-Siempling	+ + +
South Rhodesia	Marandellas	+ + +

The data of Table 3 show clearly that average daily maximum temperatures during the summer months in Rustenburg and Pongola do not differ much. However, the average daily maximum temperature in Komatipoort is quite a bit higher than in Rustenburg and Pongola. Comparing the minimum average temperatures it is clear that the nights in Rustenburg are much cooler than in Komatipoort and Pongola. There is not much difference between the average daily minimum temperatures in Pongola and Komatipoort, although the nights in Komatipport are a little warmer than in Pongola.

The average daily maximum and minimum temperatures in the Rustenburg region, as shown in Table 3, for the whole tobacco season are lower than 25°C. these temperatures in Pongola during two months (January and February) and in Komatipoort during five months (November-March) are 25°C and higher.

The degree of development of the disease as shown in Table 4 proves a close relationship with the average daily maximum-minimum temperature during the summer. The reason for this determination is the fact that powdery mildew is epidemic in Rustenburg in every season, in Pongola

it was never of any economic importance and in the Komatiport region it was altogether absent.

Comparing the average temperatures during the summer months in Rustenburg, Medan, North Carolina and Marandellas (Table 3) it is shown that there is not much difference in the maximum temperatures, not in Medan and Rustenburg, for instance. During the winter months the average maximum temperatures are much higher in Medan than in Rustenburg. The nights are much colder in Rustenburg than in Medan. The consequence is that the average daily maximum-minimum temperature in Rustenburg always is lower than 25°C; the average maximum-minimum temperature in Medan, during the months tobacco is harvested, (October-December) always is higher than 25°C. The average maximum-minimum temperatures in Marandellas are approximately the same in Rustenburg; the temperatures in North Carolina during the tobacco season are in accord with those in Medan.

Regions like Medan and North Carolina, where the days as well as the nights during the growing season are warm and consequently the average daily maximum-minimum temperature are higher than 25°C have no powdery mildew, as the data in Table 4 show. This in opposition to the fact that powdery mildew is abundantly present in Rustenburg and Marandellas where hot days and cold nights make the average daily maximum-minimum temperatures in the middle of the summer lower than 25°C.

The inhabitants of Sumatra during the Dutch reign planted tobacco in locations 650 feet and higher above sea level and the tobacco was seriously affected by powdery mildew. Because climatological data of the locations where the inhabitants raised tobacco are not available, the temperatures of Fort de Kock (2900 feet above sea level) were used. The data of Fort de Kock were only used to show that the high inland is very much cooler than the coastal regions. A comparison of the temperatures in Medan and Fort de Kock is shown in Table 3.

Both the day and night temperature in Fort de Kock is much lower than the day and night temperature in Medan. It is remarkablethat the average daily maximum-minimum temperatures in Fort de Kock are approximately the same as in Rustenburg, and it is not astonishing that the tobacco in the inland of Sumatra shows the same serious contamination as in Rustenburg.

Meteorological data from the tobacco regions in Java were not available, but the publications of Jensen and de Vries (1914) and D'Angremond (1923) show that the powdery mildew there is fairly serious; D'Angremond states, for instance, that Pandang-Siemping is an "eminent fungus land".

Altogether it can be said that the air temperatures play a very important part for the presence of powdery mildew of tobacco in certain

locations or season and also as to the degree of contamination. Turning the scale for controlling the disease is not so much the maximum or minimum daily temperature as a constant daily temperature of 25°C up or an average daily maximum-minimum temperature of higher than 25°C.

E. Relative Humidity

It is a well known fact that some of the Erysiphaceae can only develop in a very humid atmosphere and others can resist a very dry one.

Longree (1939) found that on roses, conidia of powdery mildew germinate very well at a relative humidity of 95 percent and higher, and that little germination takes place between 75 and 95 percent and no germination at all at a lower relative humidity than 75 percent. In contrast to this, Dolp (1956) found that the germination of conidia of Uncinula between the minimum and optimum temperatures are not influenced by low humidity. Yarwood (1936) showed that the Erysiphe polygoni of clover and beans can stand a lower humidity than Erysiphe plygoni of the mustard plant. Actually, to which degree relative humidity determines the presence of Erysiphe cichoreearum in tobacco is till now unknow, but in the past it was generally accepted that high humidity of the atmosphere was beneficial to the disease (D'Angremond, 1923). Levijkh (1940) maintained that under optimal circumstances of temperature, conidia of powdery mildew germinated best between 60-100 percent humidity and that at temperatures of 16-23.6°C and a relative humidity of 60-100 percent the disease will flourish best.

Comparison of the humidity of two tobacco regions within the Union of South Africa shows that the relative humidity in Komantpoort is much higher than in Thabazimbi.

The data of Table 5 show clearly that the relative humidity in Thabazimbi during a great part of the tobacco growing season is under 50 percent; the humidity during the same period in Komatipoort is 11-19 percent higher. According to D'Angremond the tobacco of Komatipoort should be strongly affected by powdery mildew, and the disease in Thabazimbi should be no problem at all. However, observations show just the opposite, because the disease is absent in Komatipoort and rather serious in Thabazimbi.

Table 5. The mean daily relative humidity at Thabazimbi and Komatipoort over the 12 months of the year.

Month	Thabazimbi	Komatipoort
I	54	67
II	57	68
III	57	70
IV	55	66
V	54	63
VI	51	62
VII	48	59
VIII	41	58
IX	35	54
X	37	55
XI	45	59
XII	44	63

Study of the contamination and development of the fungus under different circumstances of humidity and temperature shows that the humidity, relatively speaking, is of little or no important for the development of the fungus; nowhere in the investigation is the lack of growth of the fungus caused by a low humidity. This study stresses the point of the great toleration some mildew fungi have for low humidity, in accordance with the results of Yarwood.

Although powdery mildew contamination is most times attributed to high humidity, it is far more the result of a low temperature in the tobacco locations (as is also shown for Uncinula necator on grapes, by Delp, 1954). Of the two important surrounding factors for the development of powdery mildew (temperature and humidity) the temperature is by far the more important. Actually, this investigation shows that as a fact the temperature is the only determining factor for the contamination of tobacco by powdery mildew.

Summary

THE EFFECT OF TEMPERATURE AND HUMIDITY ON THE TOBACCO POWDERY MILDEW FUNGUS

The influence of temperature on the germination of conidia and on the infection of tobacco by powdery mildew was determined. For the former the minimum, optimum and maximum temperatures were found to be lower than 5°C between 24-25°C and between 30-35°C, and for the latter 5°, 23.5° and 25°C respectively.

The existence of a very close correlation between the occurrence of powdery mildew in certain tobacco areas and the average daily maximum-minimum temperatures prevailing in those areas could be shown. It was found, for example, that powdery mildew did not occur in areas in which the prevailing average daily maximum-minimum temperatures were 25°C or higher.

Relative humidity on the other hand, has much less influence than temperature on either the germination of the conidia or the occurrence of powdery mildew in different tobacco areas. It was found, for example, that the conidia could germinate under conditions in which the R. H. varied from 0 to 100 percent between temperatures of 15° and 30°C. Furthermore, no correlation between R. H. and the occurrence of powdery mildew could be found.

Expression of Gratitude

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